Deep Continuous-Time State-Space Models for Marked Event Sequences

Yuxin Chang[*1] Alex Boyd[*2] Cao Xiao[2] Taha Kass-Hout[2]
Parminder Bhatia[2] Padhraic Smyth[1] Andrew Warrington[2]

[*]Equal contribution [1]University of California, Irvine [2]GE HealthCare

Continuous-Time Event Sequences

Event data with categorical event types (“marks”):

Marked Temporal Point Process (MTPP)

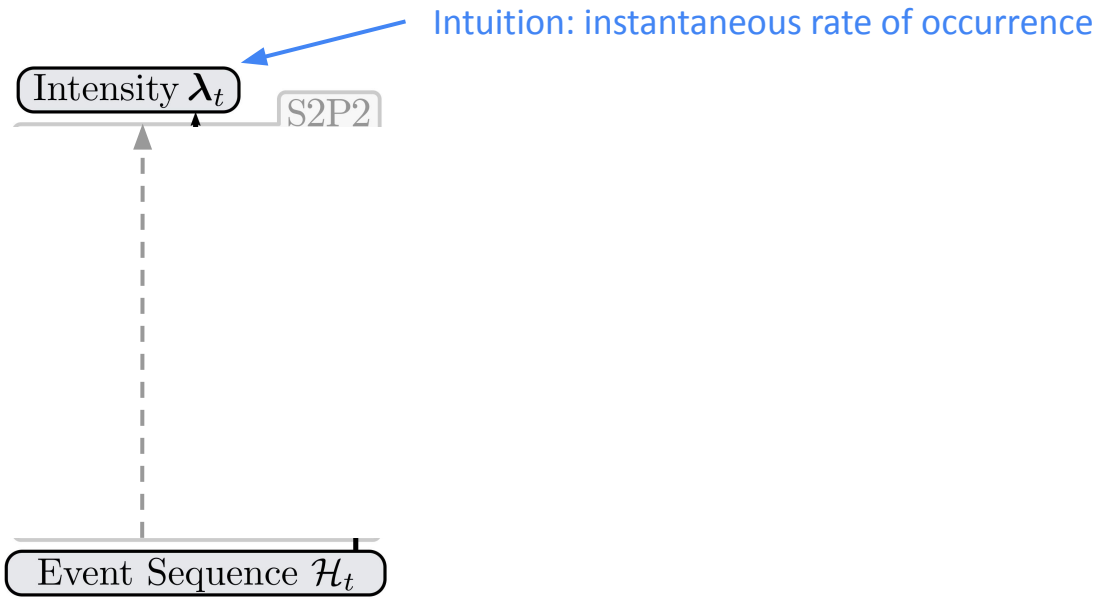
Why Another Neural MTPP Model?

Model Architecture	Linear Scaling w.r.t. Seq. Length	Parallel Computation	MTPP Implementations
RNN/LSTM	✅	❌	RMTPP (Du et al., 2016) NHP (Mei and Eisner, 2017)
Transformer/ Attention-based	❌	✅	SAHP (Zhang et al., 2020) THP (Zuo et al., 2020) AttNHP (Yang et al., 2022)
Deep State-Space Models (SSMs)	✅	✅	**State-Space Point Process (Ours)**

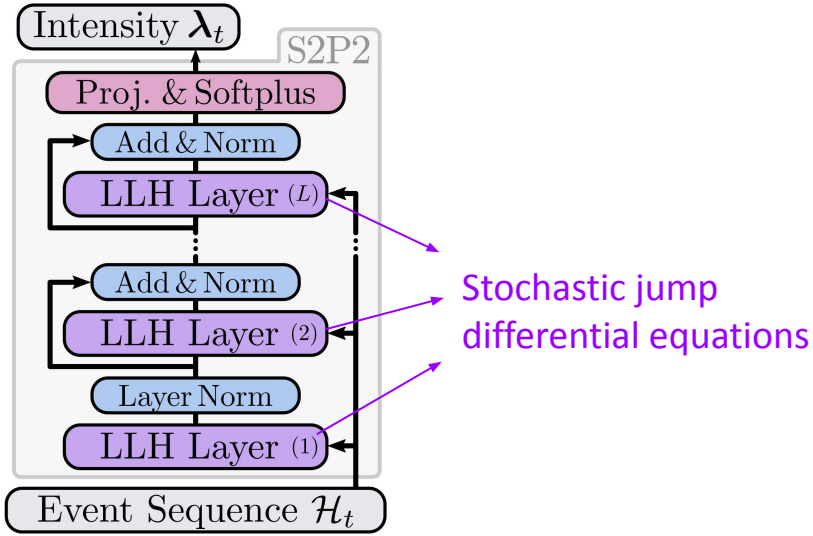
Broad ML applications:

e.g., language modeling (Gu & Dao, 2023), speech (Goel et al., 2022), vision (Wang et al., 2023; Zhu et al., 2024), reinforcement learning (Lu et al., 2023), ...

State-Space Point Process (S2P2)



State-Space Point Process (S2P2)



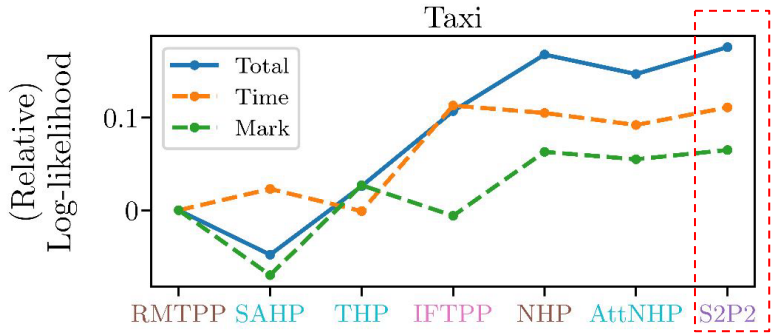
✅ **Flexible temporal modeling**

✅ **Scale up for long sequences**

✅ **Discrete events as model inputs**

✅ **Abrupt changes in intensities**

- **Intensity-based MTPPs: RNN/LSTM-based, Transformer/attention-based, SSM-based (Ours)**
- **Intensity-free MTPP: Log-normal mixture**



Evaluate goodness-of-fit by log-likelihood

$$\mathcal{L}_{\text{Total}} = \mathcal{L}_{\text{Time}} + \mathcal{L}_{\text{Mark}}$$

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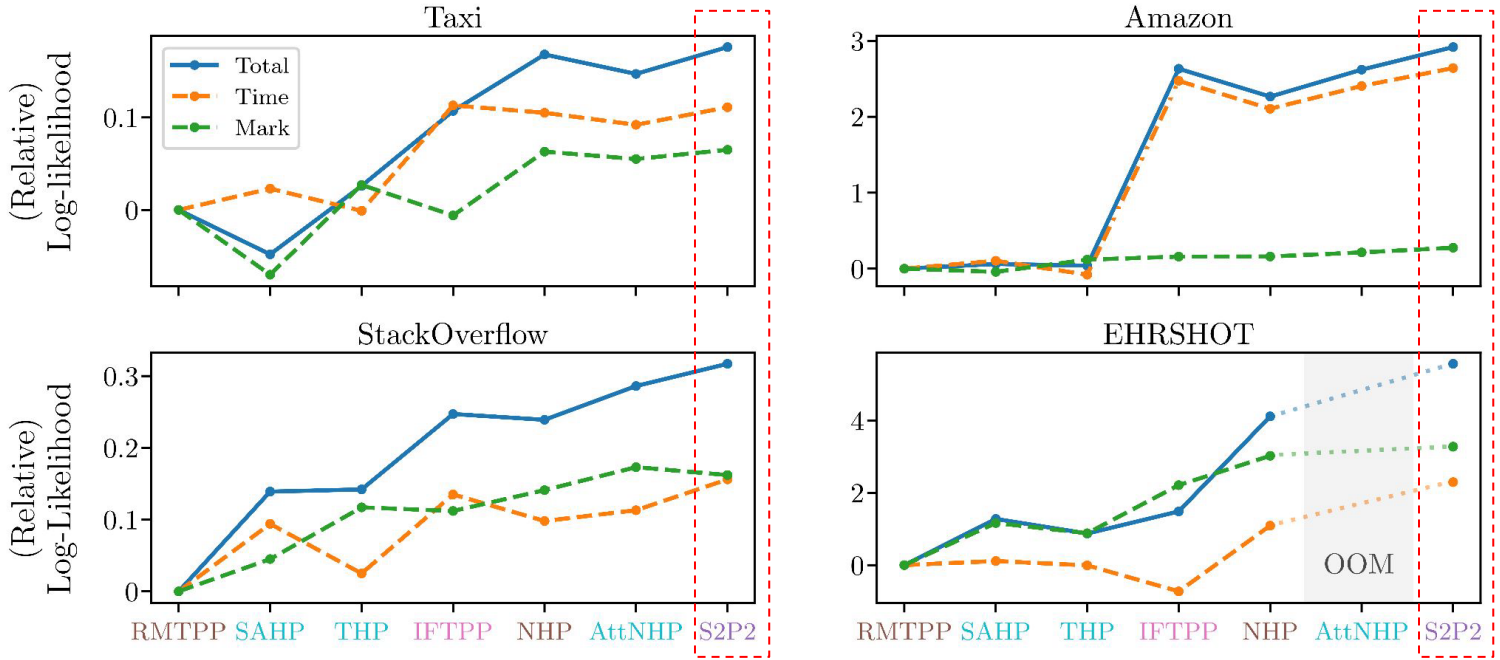

More Experimental Results in Paper

- 3 synthetic tasks
- 8 real-world datasets + 6 different metrics
- Runtime experiments

S2P2 is *expressive and efficient* across tasks and datasets, consistently outperforms baselines

Summary

- A **novel class of MTPP models** inspired by deep state-space models (SSMs)
- Flexible model leveraging **inductive bias** from parametric Hawkes process
- Both **linear scaling** and **parallel computation** for training and inference

See our poster @Wed 3 Dec, 4:30-7:30pm

Email: yuxinc20@uci.edu

Our paper:

Our model is fully integrated into EasyTPP: easy_tpp/model/torch_model/torch_s2p2.py